INTER-RELATIONSHIPS OF PALYNOFLORAS IN THE BARAKAR STAGE (LOWER GONDWANA), INDIA.*

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ABSTRACT

A survey of the Barakar miofloras from Indian Lower Gondwana has suggested a basic continuation of their general constituents. Along the lines of palaeo-drainage pattern, the lateral variations represent the miofloral-regions which are time equivalents but place variants of each other, within a broad zone. On the basis of trend of dominance and pattern of combinations, the Barakar miofloras are divisible into 3 zones, the oldest being the monosaccate/zonate/apiculate/varitrilete zone, the middle one having *Scheuringipollenites* —striate disaccate—rich flora and the youngest being the one with striate disaccate dominant phase. The lower base-line of the Barakar miofloras is located at the decline of the second monosaccate rich zone of the Talchir Series. The upper limit of the Barakar is marked by the scarcity of miospore genera in general, with the significant record of enveloping monosaccate genus *Densipollenites*.

INTRODUCTION

The Lower Gondwana (Permian) has been divided into two series: Talchir Series and Damuda Series. The Barakar Stage, named after the Barakar river which flows across this formation in the Raniganj Coalfield, is the lower most stage of the Damuda Series, underlain by the Karharbari and overlain by the Barren Measure Stages. It constitutes the main coal producing horizons of India and is widely distributed in the peninsular as well as in the extra-peninsular regions. Lithologically, these sediments are very similar, consisting entirely of sandstones with false bedding, shales and coal seams arranged in a cyclic manner. They occur in a number of basins and their stratigraphic relationship can be established by the help of palynofloras.

During the last decade, vigorous research activities in the Barakar Measures have resulted into the accumulation of important data regarding the palynological assemblages from various Gondwana basins. The qualitative as well as quantitative palynological analyses have brought forward many interesting facts about the distribution of palynofloras.

The present paper deals with the inter-relationships of these spore pollen assemblages, their nature, variation and also their extensions in time and space. It has been concluded that palynologically, this stage is divisible into 3 major zones. Laterally, the inter-basinal relationships indicate the alternative miofloral regions within the same major period but at different micro-time-planes.

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Palaeobotanical Contents of the Barakar Stage

The stratigraphical position of the Barakar Stage in the Lower Gondwana succession is as given below:

Damuda Series	Raniganj
	Barren Measures
	Barakar
	Karharbari
Talchir Series	Talchir

The following plant megafossils, are quite abundant in the Barakar Stage: *Schizoneura, Phyllotheca, Sphenophyllum, Glossopteris, Gangamopteris, Sphenopteris, Rhabdotaenia, Noeggerathiopsis, Walkomiella, Barakaria, Cordaicarpus, Samaropsis, Dadoxylon, Indoxylon, Barakaroxylon, Rhipidopsis.*

Out of these elements, the Barakar megaflora shows the dominance of *Glossopteris*, along with *Rhabdotaenia, Sphenophyllum* and *Sphenopteris.*

A number of varied miospore genera pertaining to the groups—triletes, zonates, monosaccates, disaccate—striate and non-striate, and colpate have been recorded from the sediments of the Barakar Stage. Some of the quantitatively important genera are:—

Laevigate Triletes	*Callumispora* (=*Punctatisporites*), *Hennellysporites* (=*Retusotriletes*).
Apiculate Triletes	*Lophotriletes, Apiculatisporis, Horriditriletes.*
Varitriletes	*Microbaculispora, Microfoveolatispora, Brevitriletes.*
Zonates	*Dentatispora, Indotriradites.*
Monoletes	*Latosporites.*
Disaccate non-striates	*Scheuringipollenites* (=*Sulcatisporites*), *Ibisporites, Illinites.*
Disaccate Striates	*Faunipollenites* (=*Striatopiceites*), *Striatopodocarpites* (=*Strotersporites, Gondwanipollenites*), *Primuspollenites.*

The growing information about the palynological sequences in the Lower Gondwanas of India inspired certain workers to synthesise such data in order to evaluate their significance in the biostratigraphy. Thus, the contributions by Chandra, Khan and Singh (1964), Bharadwaj (1966, 1969, 1971, 1972, 1974), Ghosh (1972), Singh and Shah (1971), Shah, Singh and Sastry (1971), Venkatachala (1972) and Srivastava (1974) are important to mention here.

Analysis of the Palynological Data

In the following account, a brief survey of different miofloral assemblages encountered in different Barakar sediments has been given. Mainly, the quantitative data have been taken into account, although the qualitative data have also been used, wherever available, for general comparison. While listing the various miospore genera, the order of percentage frequency has been maintained, the most dominant being the very first. In the following account, in some of the successions the assemblages have been reduced in number; this bracketing has been done on the basis of broad similarities (i.e. not very significant

differences) between the two successive miofloras, which have been otherwise identified as separate by the original worker.

Palynoflora from the Barakar Type Area:

The Pusai-Shampur region of the West Raniganj Coalfield, which is the type-area of the Barakar Stage, has been recently analysed by the author (Tiwari, 1973) for its palynofloras. This succession has been divided into 5 miofloral zones as given below.

V	Zone-5	*Faunipollenites, Striatopodocarpites, Scheuringipollenites, Vesicaspora.*
IV	Zone-4	*Scheuringipollenites, Ibisporites, Rhizomaspora, Striatopodocarpites, Latosporites.*
III	Zone-3	*Parasaccites*/Zonate-Cingulate, *Illinites, Scheuringipollenites.*
II	Zone-2	*Parasaccites, Brevitriletes, Callumsipora, Scheuringipollenites.*
I	Zone-1	*Callumispora, Parasaccites, Plicatipollenites.*

Between Zone-2 and Zone-3 a new element of Zonate-Cingulate has set in and hence, this line is considered to be a marker of a new phase, in this succession. Zone 1 and 2 are dated as Karharbari, while Zone 3, 4 and 5 have been assigned to the Barakar Stage.

Palyno-coloumns in Different Basins

During the last decade, a number of Barakar depositions have been palynologically investigated from various Lower Gondwana basins. The statistical analyses of miofloral assemblages from the following coalfields are available for considerations (also see Bharadwaj, 1972)—

I. Godavari Wardha Basin—Singreni Coalfield (Bharadwaj, 1971).

II. Satpura Basin—Mohpani Coalfield (Bharadwaj & Anand-Prakash, 1972); Pench-Kanhan (Bharadwaj & Anand-Prakash 1973); Pathkhera (Anand-Prakash, MS).

III. Mahanadi Basin—Talchir Coalfield (Bharadwaj & Srivastava, 1969a); Ib-river (Rampur) Coalfield (Navale & Tiwari, 1968).

IV. Chattisgarh-Rewa Basin—Chirimiri Coalfield (Bharadwaj & Srivastava, 1969); Bisrampur Coalfield (Bharadwaj & Srivastava, 1970); Korba Coalfield (Bharadwaj & Tiwari, 1964; Tiwari, 1965; Bharadwaj & Srivastava, 1973).

V. Son-Palamau Basin—Singrauli Coalfield (Tiwari, 1969, 1971; Bharadwaj & Sinha, 1969); Sohagpur Coalfield (Bharadwaj & Srivastava, 1971).

VI. Damodar Basin—W. Bokaro Coalfield (Tiwari, 1965); North Karanpura Coalfield (Bharadwaj & Tiwari, 1966; Venkatachala & Kar, 1968, 1968b; Kar, 1969, 1973); South Karanpura Coalfield (Bharadwaj & Tiwari 1968; Bharadwaj & Anand-Prakash, 1972); Raniganj Coalfield (Tiwari, 1973); Giridih Coalfield (Srivastava, 1974); Auranga Coalfield (Srivastava & Anand-Prakash, 1973).

VII. Western Himalayan Region—Kathwai Shale, Salt Range (Venkatachala & Kar, 1968).

The following palynological assemblages have been determined from the various areas listed above:

1. Singreni Coalfield	BHARADWAJ (1971):
III Assemblage C	*Scheuringipollenites, Brevitriletes, Apiculatisporis, Lahirites.*
II Assemblage B	*Scheuringipollenites, Apiculatisporis, Brevitriletes, Indotriradites.*
I Assemblage A ..	*Indotriradites, Hennellysporites, Leiotriletes, Brevitriletes.*
2. Mohpani Coalfield	BHARADWAJ AND ANAND-PRAKASH (1971):
II (Sub-zone A+B+C+D)	*Scheuringipollenites, Brevitriletes/Indotriradites, Parasaccites.*
I Zone I	*Parasaccites, Virkkipollenites, Plicatipollenites, Callumispora, Scheuringipollenites.*
3. Pench-Kanhan Coalfield	BHARADWAJ (1971):
II Assemblage 3	*Scheuringipollenites, Brevitriletes, Hennellysporites, Parasaccites.*
I { Assemblage 2	*Brevitriletes, Hennellysporites, Microbaculispora, Parasaccites.*
I { Assemblage 1	*Microfoveolatispora, Microbaculispora, Brevitriletes, Hennellysporites, Parasaccites.*
4. Pathakhera Coalfield	ANAND-PRAKASH (1972): *Scheuringipollenites, Brevitriletes, Faunipollenites.*
5. Talchir Coalfield	BHARADWAJ AND SRIVASTAVA (1969):
II Assemblage B	*Cyclogranisporites, Scheuringipollenites, Faunipollenites, Horriditriletes, Microbaculispora.*
I Assemblage A	*Brevitriletes, Microbaculispora, Scheuringipollenites, Faunipollenites, Hennellysporites.*
Assemblage	NAVALE AND SRIVASTAVA (1971): Gopalprasad Seam— *Faunipollenites, Scheuringipollenites, Striatopodocarpites Lahirites Cyclogranisporites.*
6. Ib-river (Rampur) Coalfield—	NAVALE AND TIWARI (1968):
II Assemblage Ib-1	*Scheuringipollenites, Latosporites, Brevitriletes, Lophotriletes, Horriditriletes.*
I Assemblage Ib-2	*Parasaccites, Brevitriletes, Lophotriletes, Horriditriletes, Striatopodocarpites, Scheuringipollenites.*
7. Korba Coalfield	BHARADWAJ AND TIWARI (1964):
Ghordewa, Korba and Rajgamar sectors.	
Assemblage-E	*Scheuringipollenites, Faunipollenites, Latosporites, Lophotriletes, Apiculatisporis.*
Assemblage-D	*Faunipollenites, Scheuringipollenites, Latosporites, Lophotriletes, Apiculatisporis.*
Assemblage-A	*Indotriradites/Faunipollenites, Vestigisporites, Scheuringipollenites, Hennellysporites, Apiculatisporis.*
Assemblage-B	*Indotriradites, Apiculatisporis, Faunipollenites, Vestigisporites, Scheuringipollenites.*
Assemblage-C	*Dentatispora, Parasaccites, Faunipollenites, Hennellysporites.*

When reviewed on the basis of broad groupings, these 5 assemblages can be reduced to 3 major zones as given below:—

III Assemblages (D+E) — *Scheuringipollenites/Faunipollenites*, *Latosporites*, apiculates.

II Assemblages (B+A) — Zonate, *Faunipollenites*, apiculate, *Scheuringipollenites*.

I (Assemblage C) — Cingulate, *Parasaccites*, *Faunipollenites*, *Hennellysporites*.

BHARADWAJ AND SRIVASTAVA (1973): Bore hole No. NCKB-19.

III Assemblage III — *Scheuringipollenites*, *Faunipollenites*, striates, *Latosporites*.

II Assemblage II — *Parasaccites*, *Scheuringipollenites*, *Brevitriletes*, *Primuspollenites*.

II Assemblage II — *Parasaccites*, *Brevitriletes*, *Callumispora*, *Plicatipollenites*, (zonates rare).

I Assemblage I — *Callumispora*, *Parasaccites*, *Brevitriletes*, *Lophotriletes*.

I Assemblage I — *Parasaccites*, *Plicatipollenites*, *Callumispora*, *Potonieisporites*.

8. Bisrampur Coalfield — BHARADWAJ AND SRIVASTAVA (1970): 21 bore core coal samples from Bhatgaon, Khargaon and Songara blocks.

III Assemblage D — *Brevitriletes*, *Horriditriletes*, *Microbaculispora*, *Scheuringipollenites*.

III Assemblage C — *Brevitriletes*, *Scheuringipollenites*, *Faunipollenites*, *Horriditriletes*, *Microbaculispora*.

II Assemblage B — *Indotriradites*, *Microbaculispora*, *Brevitriletes*, *Hennellysporites*, *Horriditriletes*.

I Assemblage A — *Microbaculispora*, *Dentatispora*, *Brevitriletes*, *Hennellysporites*, *Callumispora*.

9. Chirimiri Coalfield — BHARADWAJ AND SRIVASTAVA (1968):

Assemblage C — *Microbaculispora*, *Hennellysporites*, *Lophotriletes*, *Scheuringipollenites*, *Potonieisporites*.

Assemblage B — *Microbaculispora*, *Indotriradites*, *Lophotriletes*, *Hennellysporites*, *Scheuringipollenites*.

Assemblage A — *Microbaculispora*, *Scheuringipollenites*, *Lophotriletes*, *Faunipollenites*, *Indotriradites*.

The general trend of percentage frequency of various groups suggests the reduction of above assemblages into one as given below:

I (ii) Assemblage C — *Microbaculispora*, *Hennellysporites*+apiculates.

I (i) Assemblage A+B — *Microbaculispora*, *Indotriradites*, apiculates, *Hennellysporites*.

10. Sohagpur Coalfield — BHARADWAJ AND SRIVASTAVA (1971): Bhaskarpara, Kutkona and Batura blocks.

Zone IV — *Scheuringipollenites*, *Faunipollenites*, *Striatopodocarpites*, *Lahirites*.

Zone III — *Brevitriletes*, *Horriditriletes*, *Scheuringipollenites*, *Lophotriletes*, *Microbaculispora*.

Zone II — *Brevitriletes*, *Indotriradites*, *Microbaculispora*, *Hennellysporites*.

Zone I — *Brevitriletes*, *Scheuringipollenites*, *Faunipollenites*, *Lahirites*, *Hennellysporites*.

Zone II and III could be united because of their affiliations in the trends of *Scheuringipollenites* and apiculate trilete genera; similarly Zone I can be amalgamated with II and III for broader considerations since it does not show a significant miofloral break. Thus, only two major assemblages could be represented in this coalfield as given below—

II Zone IV — *Scheuringipollenites*, Striated-disaccate, *Illinites*.

I Zone I, II, III — Apiculates, varitriletes, zonates; *Scheuringipollenites.*

The Churcha seam worked out by NAVALE AND TIWARI (1967) palynologically finds its place in the Lower Assemblage of the Sohagpur Coalfield, as shown above.

11. Singrauli Coalfield — BHARADWAJ AND SINHA (1969), TIWARI (1969, 1971).

IV Jhingurdah Assemblage — *Scheuringipollenites, Faunipollenites, Ibisporites, Striatopodocarpites, Lophotriletes, Brevitriletes.*

Panipaheri and Khadia not yet known.

III Purewa Assemblage — *Scheuringipollenites, Ibisporites, Brevitriletes, Latosporites, Horriditriletes.*

II Turra Assemblage — *Scheuringipollenites, Indotriradites, Dentatispora, Brevitriletes, Parasaccites.*

I Kota Assemblage — *Dentatispora, Indotriradites, Scheuringipollenites, Callumispora, Brevitriletes, Parasaccites.*

12. Auranga Coalfield — SRIVASTAVA AND ANAND-PRAKASH (1973):

Tubed and Jagaldaga areas—

II
- Sookri River S/4, S/5 — *Scheuringipollenites, Cyclogranisporites, Faunipollenites, Horriditriletes, Striatopodocarpites.*
- Bagdagga quarry-+Sookri River Lr. samples S/3. — *Thymospora, Scheuringipollenites, Faunipollenites, Horriditriletes.*

I Jagaldaga quarry, Bagdagga Nala (except B2/1) — *Scheuringipollenites, Faunipollenites, Horriditriletes, Striatopodocarpites, Cyclogranisporites Latosporites.*

13. North Karanpura Coalfield — BHARADWAJ AND TIWARI (1966):

8 bore-hole samples from Bachra area :

Although, two assemblages have been suggested by BHARADWAJ AND TIWARI (1966) the over all mioflora belongs to one major biozone. This zone could well be termed as *Scheuringipollenites—Faunipollenites* zone (with significant *Lophotriletes* and *Latosporites*).

VENKATACHALA AND KAR (1968b): Barakar exposures near Lungatoo:

The 3 exposures, broadly speaking, contain similar mioflora—domintaed by striated disaccate and *Scheuringipollenites*, i.e. *Striatopodocarpites* + *Faunipollenites* dominant, *Scheuringipollenites* significant.

KAR (1969): Bore core (Bore hole no. K-5) from the Baral-Raniganj Kevendai area: The Barakar-zone (only one sample) consists of dominating striated disaccate (*Striatopodocarpites* + *Faunipollenites*) along with *Scheuringipollenites* as a subdominant genus.

VENKATACHALA AND KAR (1968): Badam area—

II Zone C — *Striatites, Lahirites, Hindipollenites, Striatopodocarpites, Faunipollenites, Lophotriletes, Hennellysporites.*

I
- Zone B — *Lophotriletes, Apiculatisporis, Microbaculispora, Hennellysporites.*
- Zone A — *Microbaculispora, Lophotriletes, Apiculatisporis.*

KAR (1973): Bore-hole No. KB-21—

IV Assemblage 5 — *Striatopodocarpites, Scheuringipollenites, Cuneatisporites, Parasaccites, Barakarites.*

III Assemblage 4 — *Parasaccites, Plicatipollenites, Striatites, Scheuringipollenites.*

II
- Assemblage 3 — *Microbaculispora, Parasaccites, Cyclogranisporites, Callumispora.*
- Assemblage 2 — *Callumispora, Parasaccites, Plicatipollenites, Cyclogranisporites.*

I Assemblage 1 *Parasaccites, Plicatipollenites, Callumispora, Cyclogranisporites.*

KAR (1973): Bore hole No. KBM-19—

II — Assemblage 4 *Striatopodocarpites, Scheuringipollenites, Barakarites, Brevitriletes.*

II — Assemblage 3 *Striatopodocarpites, Scheuringipollenites, Parasaccites.*

I — Assemblage 2 *Parasaccites, Indotriradites, Striatopodocarpites.*

I — Assemblage 1 *Indotriradites, Parasaccites, Callumispora, Cyclogranisporites.*

14. South Karanpura Coalfield BHARADWAJ AND ANAND-PRAKASH (1972a): Argada 'S' seam; the lowest-but-one seam in this region:

Scheuringipollenites, Brevitriletes, Lophotriletes, Ibisporites, Parasaccites, Ginkgocycadophytus.

BHARADWAJ AND TIWARI (1968): 67 bore core samples from 6 bore holes in the Saunda and Gidi areas:

II — Zone III *Microbaculispora, Cyclobaculisporites, Horriditriletes, Scheuringipollenites, Faunipollenites.*

II — Zone II *Cyclobaculisporites, Scheuringipollenites Faunipollenites, Horriditriletes, Striatopodocarpites.*

I Zone I *Scheuringipollenites, Faunipollenites, Striatopodocarpites, Cyclobaculisporites, Microbaculispora, Horriditriletes.*

15. West Bokaro Coalfield TIWARI (1965): Pindra, Datma and Topa seams—

Faunipollenites, Scheuringipollenites, Horriditriletes, Lophotriletes Latosporites; Barakarites rare but qualitatively important.

16. Raniganj Coalfield TIWARI (1973): Pusai and Khudia nala section, west of Barakar River. Palynological succession has been divided into 5 zones (already given on page 111).

17. Giridih Coalfield SRIVASTAVA (1973): Sukhni river section and colliery samples—

III Assemblage C *Scheuringipollenites, Brevitriletes, Faunipollenites.*

II Assemblage B *Illinites, Scheuringipollenites, Parasaccites.*

I Assemblage A *Parasaccites, Brevitriletes, Callumispora.*

18. Rajmahal Region MAHESHWARI (1965), Bansloi River—Assessment based on qualitative analysis:

Striates, *Scheuringipollenites, Barakarites, Parastriopollenites.*

19. Kathwai shales, Salt Range VENKATACHALA AND KAR 1968 (only qualitative); Carbonaceous shale 25 ft. above the Talchir Boulder bed from Kathwai Salt Range:

Plicatipollenites, Barakarites, Potonieisporites, Indotriradites, Corisaccites, Hamiapollenites, Striatites. Decussatisporites, Striasulcites.

INTER-RELATIONSHIP OF THE LOWER GONDWANA BASINS

The coal has been deposited in the fresh water basins of the Indian Peninsula. There was an extensive ocean along the northern region of the subcontinent in Permian times. According to Fox (1931, 1934) the Gondwanas in India were deposited in block faulted basins and the main faults seem to have been formed simultaneously with the deposition in the basin. Some of these basins were inter-connected and the water, along with vegetational debris, was drained mostly towards the north. The Godavari basin was connected with Satpura basin which in its turn had an outlet towards the north. The Mahanadi basin which was connected with South Rewa for its discharge and ultimately channelling out towards the north. There are some evidences, (Fox, 1934) which suggest that the

Son and Damodar Gondwanas were the parts of a single drainage system, letting out their waters somewhere towards the east-north-east.

However, the conclusions derived by JHINGRAN (1967) on the basis of petrological and chemical characters of the coals from Son Valley basin and Damodar Valley basin are suggestive of their different nature. According to him, there seems to be some possibility of a connection between Son and Mahanadi basins on the basis of similarity in coal characters.

AHMAD (1961) is of the opinion that the Lower Gondwana coals in India are autochthonous in origin and not allochthonous and porbably it implies that there were no basinal connections. He also opines that these sediments were not deposited in the faulted basin as believed by Fox (1934) but mostly the faults were of later origin. AHMAD (1961) has also shown the significance of the isopach lines and has derived that the thickness of deposited strata generally decreases as one proceeds from east towards the west or north-west in Peninsular India.

GHOSH AND BANDYOPADHYAY (1969) are of the opinion that the palaeoslopes and consequently the drainage pattern varied from region to region. According to these authors there were five important drainage systems in the peniusula: The Godavari, connected with Narmada (Satpura) basin drained off in the west; the Mahanadi valley was connected with Son-Koel basin which ultimately discharged in the north-east. Damodar valley had a separate drainage towards the east which turned towards north-east, connecting itself with the Rajmahal-Purnea regions and then draining off in the Tethys. In general, GHOSH AND BANDYOPADHYAY (1969) agree with the opinion of Fox (1931, 1934) excepting that about the Son-Damodar union.

The review of opinions, thus, indicates that the deposition of Lower Gondwana has taken place in valleys (formed before or subsided simultaneously or even in some cases afterwards) which were connected in a certain pattern for their drainage. Although, the isopach lines show a west-ward decrease in the thickness of the strata, there may not be any direct relationship between the palaeoslopes and the isopach lines. The theory of autochthonous origin of Indian Gondwana coals (without interbasinal connections) does not hold good for every basin or every seam because of the lack of *in situ* plant remains and also that of the typical fire clay at the bottom of most of the coalseams. The resemblance in the petro-chemical nature of widely separated coals (see JHINGRAN, 1967), and the basic alliance in the miofloras from different basins also suggest that these basins were inter-connected, may be partly, in a definite pattern with a set of drainage system, which caused an intermixing of the "raw material". In such a system, it can be presumed safely that for a certain time, in a particular basin, the deposition has taken place and resulted into a very thick seam while at another time, the vegetational contents have partially drifted to the next basin and got deposited there.

This means that most of the thick seams originated from the local vegetation and only very little matter was drained off in the adjoining basin, probably due to faster subsidence. Even then, the basins remained connected and the flow was continued during most of the preceding as well as succeeding depositional time. Therefore, it shall be erroneous to generalize that all the coals were autochthonous. An opponent of the 'link theory' can question about the discontinuity of deposition found at the present time from basin to basin. This, however, is so because mostly the connections were active, flowing through the base rocks, and were very small in dimensions which minimized their possibilities of getting preserved. If we accept the theory of drainage links, the partial drift

of vegetational debris was definitely there, thus suggesting that the coal was of mixed nature in origin. For such a condition a new term—"*Mixtochthonous*" is being proposed here which means that the coal was originated partly from the local vegetation and partly from the drifted one, from a different basin. To conclude upon this point, the evidences suggest that the pattern of drainage was mostly on the lines suggested by Fox (1934) i.e. the Godavari basin was discharging in the Satpura basin which in its turn drained off in the west. This twin-basin system was probably separated from the Mahanadi and Son by a high land in between. The Mahanadi basin was connected with S. Rewa as well as with Son (Ghosh & Bandyopadhyay 1969) and probably did not join the Damodar Valley. The three major basin-complexes (Godavari→Satpura→West; Mahanadi→S. Rewa→Son→north-north-east; Damodar→Rajmahal→east-north-east) were presumably separated by the high lands and mountain ridges in between them.

Vertical Distribution of Palynofloras

The coalfields, from where the Barakar and related strata are palynologically known, are arranged basin wise on the above derived lines and the available data regarding the palynological succession in them have been given in Table 1.

The vertical placements of the different miofloras are based upon the stratigraphical importance of the various elements. The importance of the dominating miospore genera has been determined after analysing the miofloral assemblages in the well dated Barakar and related rocks; such an analysis reveals their stratigraphical relationships with other genera, in the following manner (miospore genera arranged in order of relative stratigraphical super-imposition).

{ *Barakarites*
{ *Striatopodocarpites*

{ *Latosporites*
{ *Faunipollenites*

Scheuringipollenites

{ *Apiculatisporis*
{ *Brevitriletes*

{ *Microbaculispora*
{ *Microfoveolatispora*

Indotriradites
Dentatispora
Callumispora

{ *Parasaccites*
{ *Plicatipollenites*

After arranging the known miofloras on the above lines (Table 2) the succession of miospores from the Barakar and related strata can be divided by three distinct lines of division, here named as—

Striate-disaccate—line
Scheuringipollenites—line
Monosaccate—Zonate-Apiculate—line

Below the *Monosaccate-Zonate-Apiculate*-line, the monosaccate genera like *Parasaccites* along with *Callumispora* (=*Punctatisporites*) dominate the scene. Above this line and below the *Scheuringipollenites*-line, the zonates (e.g. *Indotriradites*) and apiculates (*e.g. Apiculatisporis*) preponderate in various changing combinations. Above the *Scheuringipollenites* line, the genus *Scheuringipollenites* establishes its supremacy in association with the striates in general.

Above the *Striate*-line, the striation-bearing-disaccate genera such as *Striatopodocarpites*, *Faunipollenites*, *Striatites* etc. are in super-abundance.

A careful perusal of the Table 1 further reveals a regular trend of change in the members of the dominant association of each assemblage. The monosaccates are in an overall dominance below the *Monosaccate-Zonate-Apiculate*-line. Above this, the monosaccates may remain in prominence but zonate-cingulates also gain significance and they continue to show the changing partners; for example in the lower assemblage of Ib-river Coalfield (Mahanadi basin) the zonates are rare, in association with *Parasaccites* and so also in the S. Korba Coalfield, but in N. Korba (BHARADWAJ & TIWARI, 1964) the zonate-cingulate genera overwhelmingly dominate the mioflora. In Bisrampur, Chirimiri and Sohagpur Coalfields (South Rewa region) the zonate spores come more or less in the second place of importance and the apiculates as well as *Microbaculispora* come in prominence. Similarly, in the Son and Damodar Valley Coalfields also, the zonate-cingulate miospores laterally show a changing pattern of combinations with apiculates and saccates etc. To illustrate the latter statement we have a "zonate + *Scheuringipollenites*" and "*Scheuringipollenites* + zonate" complexes in the older seams of the Singrauli Coalfield. In the lower horizons of North Karanpura Coalfield (KAR, 1973) it is singular to note that the *Microbaculispora-Callumispora*-zone comes between two monosaccate zones while it is mostly a *Callumispora* rich zone elsewhere. This is dated to be Lower Karharbari in age. Above the second monosaccate rich zone, the *Indotriradites* plus *Parasaccites* combination occurs. Same combination with more of *Parasaccites*, is also present above the *Parasaccites* + *Brevitriletes* + *Callumispora*-zone of the Raniganj Coalfield (TIWARI, 1973). That the zonate cingulate spores change their pattern of occurrence as well as their partners in various basins of the peninsular India (see Table 2) is evident from the following analysis:

Godavari	Satpura	Mahanadi
ZONATES + apiculates + monosaccates	*Scheuringipollenites* + ZONATES + Apiculates	*Parasaccites* + Apiculates + ZONATES

S. Rewa		Son	
ZONATES + Apiculates + *Parasaccites*	*Microbaculispora* + ZONATES + Apiculates	ZONATES + *Scheuringipollenites*	*Scheuringipollenites* + ZONATES

Damodar	N. W. outliers
ZONAETS + Monosaccates.	Monosaccates + ZONATES

Sometimes the triletes and zonates do not show consistency, qualitatively or quantitatively, even within a basin, and hence much importance may not be attached to them. At the same time, the wide range of their occurrence and super-dominance in percentage in certain miofloras are the indications of their significance in palynostratigraphy. However, more data are needed to establish the exact behaviour of these groups but as such, at the present state of our knowledge they should not be left without giving any due importance in stratigraphical considerations.

The three lines of miofloral changes as derived earlier, divide the Barakar mioflora

into three distinct zones. In the lower zone (ZONE B I) in Table 1, the overall composition is of the zonate-apiculate-monosaccate-varitriletes pattern, as has been discussed above, while in the middle zone (ZONE B II) *Scheuringipollenites-Faunipollenites-Latosporites*-apiculate pattern is characteristic. The *Scheuringipollenites*-line indicates the sudden dominance of the genus; the border-line cases, however, show some cross-over elements from below (i.e. from Zone B-I).

Above the *Striate*-line, within the ZONE B III, the genera like *Striatopodocarpites*, *Faunipollenites*, *Striatites* etc. dominate the scene while *Scheuringipollenites* becomes a subdominant genus. In this zone too, the border-line-assemblages show the mixing up of older elements, which however, is very natural in any transitional miofloral. However, the placement of the indeterminate marginal floras above or below the line has been decided on the grounds of their overall contents with younger or older affinities respectively.

"MIOFLORAL REGIONS", LATERAL VARIATION AND PALAEODRAINAGE

It is derived from the above analysis that the presently available data are indicative of certain trends and modes of changing miofloral composition along the palaeo-drainage lines in general. From one basin to another, the continuity of the vegetational constituents—howsoever meagre it may be—influences the chain of assemblages laterally and at the same time, miofloral elements of local influence are also introduced into these depositions. These miofloral changes along the inter-basinal-drainage-line could be clearly marked out and can be separated into "miofloral-regions" or the "blocks of lateral variations" (see Table. 1). Although, these "miofloral regions" (or the "blocks") cannot be presumed simply to be the "exact age-equivalents" due to their significant differences, they could, however, represent the smaller units of a single major time-span (i.e. a Zone). Their differences are presumably due to the microclimatic variations in the different depositions, which are determined by the finer time disparity. Thus, for example, during the broad time-span of Zone B-I (Table 1), the monosaccates and apiculates in Mahanadi valley, monosaccates and zonates in South Rewa basin, and apiculates and varitriletes in the Son river basin constitute the different "miofloral-regions"; these differences normally seem to exist because of the lateral variation. They may, however, represent the differences in the time plane, at least in some of the cases. Although the complete palynological successions in each and every coalfield of the Lower Gondwana must be investigated to adopt a line of explanation for such variations, yet at the present stage of our knowledge the reliably well dated, known data have also revealed certain facts. Thus, for example, on one hand the *Scheuringipollenites* + zonates + apiculate rich flora of the Mohpani Coalfield (BHARADWAJ & ANAND-PRAKASH, 1973) has been found in the conformable sediments above the Talchir lithology, while on the other, in the same stratigraphical position, a miofloral rich in monosaccates + zonates + *Illinites* has been found in the Raniganj Coalfield (TIWARI, 1973). These two, stratigraphically equivalent miofloras obviously differ in their spore-pollen constituents. According to the line of argument followed here, these two miofloras belong to the same big time-span (i.e. Zone B-I, Lower Barakar Stage) but representing two "finer" time planes, i.e. they are "*time-variants*" within the Lower Barakar. In the same way, two adjacent miofloras with minor variations (most elements in common) can be termed as the lateral variants or the "*place-variants.*" Within a miofloral zone (i.e. Broad Zone) which flora is a *time-variant* or a *place-variant* of any given flora, can be determined only when the succession in two regions under comparisons are fully and completely known right from the basal rocks of the Talchir lithology.

The monosaccate rich flora indicates a glacial or a near-glacial type of very cold climate, the zonate-cingulate (lycopsids) as well as the apiculate-varitriletes (filician-affinity) spore point towards the cool and humid climatic conditions. The changing combinations in some groups in the early Barakar suggests an unstability in the early climate i.e. in cool and less cool phases, in the widely apart basinal regions. The dominating disaccate spores are diagnostic of the warm-semi-humid type of forest growth. On this line of observations the mioflorisites is clearly supporting the palaeo-climatological views already in acceptance that in the Lower Gondwana times the climate had started with glacial-cold at the base and gradually grown to be cool and humid, less-cool and humid, and ultimately warm and semi-humid. At the close, however, it became warm and arid.

The Limits of Barakar Mioflora

During the recent years, many attempts have been made to synthesise the palynostratigraphy of Indian Lower Gondwana deposits, and suggestions have been put forward for delimiting the lower and upper limits of the Barakar palynofloras. Following is the summary of some of the important opinions regarding this problem. Dominant spore groups or genera are indicated in capital letters.

1. Chandra, Khan and Singh (1964): Characteristic assemblage of the Barakar Stage: decreasing monosaccates, increasing disaccates and dominant asaccate.

2. Bharadwaj (1966):

Barren Measures—Striates, *Scheuringipollenites*, *Densipollenites*

Upper Barakar—Scheuringipollenites, Striates, *Horriditriletes* *Leiotriletes*, *Cyclobaculisporites*.

Lower Barakar—Zonates, *Scheuringipollenites*, *Hennellysporites*, *Microbaculispora*, *Lophotriletes*.

Upper Karharbari—Parasaccites, *Faunipollenitees*, *Striatites*, *Scheuringipollenites*.

3. Bharadwaj (1969):

Barreen Measures—Striate-disaccates, apiculates, non-striate disaccates, radial monosaccates, varitriletes.

B A R A K A R

Upper—Apiculates, striate—disaccates, non-striate disaccates, varitriletes, monocolpates.

Middle—Varitriletes, apiculates, striate—disaccates, non-striate disaccates

Lower—Zonates (restricted), apiculates, varitriletes, monosaccates, striate-disaccates, non-striate disaccates.

Karharbari Radial monosaccates, striate disaccates, non-striate disaccates.

4. Bharadwaj (1971):

Barren Measures Lower—Striate disaccates, *Scheuringipollenites*, *Densipollenites*.

B A R A K A R

Upper—Striate Disaccates, *Scheuringipollenites*, apiculates.

Middle—Apiculates, striate disaccates or *Scheuringipollenites*.

Lower—Zonates/Varitriletes, apiculates, radial monosaccates.

Table 1—Distribution of important Miospore Genera in various coal-fields. In individual assemblage, the genera are listed in order of dominance. The relative position of each assemblage has been determined on the basis of its constituents.

STAGES	BASINS	GODAVARI WARDHA	SATPURA			MAHANADI		CHHATTISGARH-REWA				SON-PALAMAU			DAMODAR					W. HIMALAYAN REGION
	COALFIELD → / MIOFLORAL ZONE ↓	SINGRENI	MOHPANI	PENCH-KANHAN	PATHA-KHERA	TALCHER	IB-RIVER (RAMPUR)	KORBA (SOUTH)	KORBA (NORTH)	BISRAMPUR	CHIRIMIRI	SOHAGPUR	SINGRAULI	AURANGA	NORTH KARANPURA	SOUTH KARANPURA	WEST BOKARO	RANIGANJ JHARIA	GIRIDIH	RAJMAHAL REGION	SALT RANGE
BARREN MEASURE	DENSIPOLLENITES														*Striatopodocarp. Faunipoll. Densipollenites Scheuringipoll.*			*Striatopodocarp. Faunipoll. Densipollenites Scheuringipoll.*		*Faunipoll. Striatopodocarp. Scheuringipoll. Densipollenites*	
UPPER BARAKAR	LINE														*Striatites Lahirites Striapodocarp. Faunipollenites Lophotriletes*					*Striates Parasaccites Scheuringipoll. Densipollenites*	
	B-III					*Faunipollenites + Striatopodocarp. Scheuringipoll. Cyclogramisp.*								*Thymospora/ Cyclograni. Striates Scheuringipoll. Apiculates*	*Striatopodocarp. Faunipollenites Scheuringipoll. Barakarites*	*Horriditriletes/ Microbaculispora Striates/ Scheuringipoll.*	*Faunipollenites + Scheuringipoll. Apiculates + Latosporites Barakarites*	*Faunipollenites Striatopodocarp. Scheuringipoll. Verrucosporites*			
	STRIATE DISACCATE																				
MIDDLE BARAKAR	LINE							*Scheuringipoll. Faunipollenites + Striates Latosporites Brevitriletes Lophotriletes*	*Scheuringipoll. Faunipollenites Brevitriletes Latosporites + Lophotriletes*			*Scheuringipoll. Faunipollenites Striate/ Apiculates*			*Scheuringipoll. Faunipollenites Lophotriletes*	*Scheuringipoll Latosporites Horriditriletes Faunipollenites*		*Scheuringipoll Rhizomaspora Striatopodocarp. Latosporites*			
	B-II												*Scheuringipoll. Ibisporites Brevitriletes Latosporites Horriditriletes*	*Scheuringipoll. Striates Apiculates Latosporites*		*Scheuringipoll. Brevitriletes Laphatriletes Horriditriletes*			*Scheuringipoll Brevitriletes Faunipollenites*		
	SCHEURINGIPOLLENITES	*Scheuringipoll. Apiculates Striates*		*Scheuringipoll. Brevitriletes Hennellysporites*	*Scheuringipoll. Brevitriletes Faunipollenites*		*Scheuringipoll. Latosporites Lophotriletes Brevitriletes Horriditriletes*	*Scheuringipoll. Striates Brevitriletes + Parasaccites*													
LOWER BARAKAR	LINE	*Scheuringipoll. Apiculates Zonates*	*Scheuringipoll. Brevitriletes/ Indotriradites Parasaccites*			*Cyclogranisp. Scheuringipoll. Faunipollenites Horriditriletes*						*Brevitriletes Scheuringipoll. Microbaculisp. Indotriradites*	*Scheuringipoll. Indotriradites + Dentatispora Brevitriletes Parasaccites*		*Microbaculispora/ Apiculates Hennellysporites Striates*				*Illinites Scheuringipoll. Parasaccites*		
	B-I	*Zonates/ Apiculates Monosaccates Hennellysporites*		*Brevitriletes Microbaculispora Microfoveolatisp. Hennellysporites*		*Brevitriletes Microbaculispora Scheuringipoll. Faunipollenites*		*Indotriradites/ Faunipollenites Scheuringipoll. Apiculates*	*Indotriradites Microbaculispora Brevitriletes Hennellysporites*	*Microbaculispora Indotriradites Hennellysporites Apiculates*			*Dentatispora/ Indotriradites Scheuringipoll. Callumispora Brevitriletes Parasaccites*		*Indotriradites/ Parasaccites Striates Callumispora*			*Parasaccites Dentatispora Illinites Scheuringipoll.*			
	MONOSACCATE ZONATE APICULATE						*Parasaccites Brevitriletes Lophotriletes Horriditriletes Striatopodocarp. Scheuringipoll.*	*Parasaccites/ Scheuringipoll. Brevitriletes Premuspoll. Striates*	*Dentatispora Parasaccites Faunipollenites Hennellysporites*	*Microbaculispora Dentatispora Brevitriletes Hennellysporites*										*Monosaccates Zonates Corisaccites Distriatites*
KARHARBARI	LINE		*Parasaccites Virkkipollenites Scheuringipollenites Callumispora*					*Parasaccites Brevitriletes Callumispora Plicatipoll.*							*Parasaccites Plicatipoll. Limitisporites Crucisaccites*			*Parasaccites Brevitriletes Callumispora Scheuringipoll.*	*Parasaccites Brevitriletes Callumispora*		
								Parasaccites Callumispora Brevitriletes Plicatipoll.							*Callumispora/ Microbaculispora Parasaccites Plicatipollenites*			*Callumispora Parasaccites Plicatipoll.*			

Karharbari—RADIAL MONOSACCATES, SCHEURINGIPOLLENITES, apiculates.

5. BHARADWAJ (1974):

Barren Measures—STRIATES, *Scheuringipollenites*, monocolpates.

BARAKAR — Upper—STRIATES, *Scheuringipollenites*.
Middle—APICULATES, *Scheuringipollenites*, monocolpates.
Lower—ZONATE/VARITRILETES, striate and non-striate disaccates, monosaccates.

Karharbari, Upper—RADIAL MONOSACCATE, striate, nonstriate disaccates.

6. VENKATACHALA (1972):

Barren Measures—STRIATE DISACCATE, nonstriate disaccate, *Densipollenites*.
Barakar—STRIATE-DISACCATE, nonstriate disaccate, monosaccates, zonates, apiculates.
Karharbari—MONOSACCATES, PUNCTATISPORITES, apiculates, striate disaccate.

7. SHAH, SINGH AND SASTRI (1972):

Barakar—Varitriletes, Zonates, Reticuloid-striate, *Barakarites*, *Striapollenites*, *Maculatasporites*.
Karharbari—Monosaccates.

8. SRIVASTAVA (1974):

Barren Measures, Lower—STRIATES, *Scheuringipollenites*, *Densipollenites*.

BARAKAR — Upper—STRIATE DISACCATES, *Scheuringipollenites*, apiculates.
Middle—APICULATE TRILETES, *Scheuringipollenites*, *Faunipollenites*.
Lower—ZONATES, VARITRILETES, *Scheuringipollenites*.

Karharbari—*Scheuringipollenites*, APICULATES, monosaccates.

It is apparent from the above data that the assemblages characteristic of the various horizons have been sinthesised from time to time on the basis of the data then available.

The problem of the lower limit of Barakar Stage is directly related to the problem of the Karharbari mioflora. The evidences, so far at our hand to bank upon suggest that the monosaccate-rich assemblage (*Parasaccites*+*Plicatipollenites*) with *Callumispora* (=*Punctati sporites*) marks the Talchir Stage (having typical Talchir lithology) in most of the regions (BHARADWAJ 1966, 1971). As suggested by BHARADWAJ (1974), immediately after the radial monosaccate zone of the Talchir Stage, there exists a *Callumispora* zone, and once again the *Parasaccites* zone (the *second* zone of radial monosaccates) repeats, although with a difference. This latter assemblage, recognized in most of the sequences, ordinarily suggests a miofloral continuity with the typical Talchir beds. However, as interpreted by BHARADWAJ (1974), the younger zone of radial monosaccate, corresponding to the younger Karharbari beds, represents the glacial phase of a second glacialtion, of which the interglacial extends through the Barakar Stage. Moreover, *Sulcatisporites* (=*Scheuringipollenites*) which becomes dominant in the succeeding strata commences as a significant associate in this zone. Hence, BHARADWAJ (1974) considers it reasonable to include the younger radial monosaccate zone also in the Barakar Stage. However, as such it is equally reasonable to

propose that Karharbari mioflora as a whole is closer to the Talchir mioflora, of course, with more diversification of elements which distinguishes the two. The idea of the Karharbari Stage is also founded on the general similarities of megafossils between the strata immediately overlying the Talchir shales.

Therefore, the monosaccate dominance with somewhat diversified elements in the coal measures should be regarded as Karharbari palynoflora thus the second zone of monosaccates dominance, marks the end of the Talchir Series. Significantly just after this phase, the mioflora changes considerably showing a miofloristic break. This line (the end of the second monosaccate zone) has been taken in the present work as the beginning of the Barakar mioflora.

Table-2—1. Monosaccate/Zonate/Apiculate-line, 2. *Scheuringipollenites*-line, 3. Striate-disaccate-line, 4. *Densipollenites*-line. B-I a to e: unit assemblages in order of superposition, interchangeable within the finer zones in Lower Barakar. B-II a, b: finer zones in Middle Barakar. Dominant spore groups or genera are indicated by capital letters.

Barren Measures			FAUNIPOLLENITES, STRIATOPODOCARPITES, *Scheuringipollenites*, *Densipollenites*, *Barakarites*
	4		
B	U	B-III	
	P		
	P		FAUNIPOLLENITES, STRIATOPODOCARPITES,
	E		*Scheuringipollenites*, *Latosporites*,
A	R		*Barakarites*
	3		
	M	B-II	
R	I		b.—SCHEURINGIPOLLENITES, *Faunipollenites*,
	D		*Latosporites*, *Apiculatisporis*
	D		
A	L		a.—SCHEURINGIPOLLENITES/BREVITRILETES/
	E		apiculates, striates
	2		
		B-I	
K	L		e.—SCHEURINGIPOLLENITES, APICULATES,
			Microbaculispora, Zonates
	O		d.—BREVITRILETES, MICROBACULISPORA,
A			*Scheuringipollenites*, Zonates
	W		c.—ZONATE, APICULATES, *Parasaccites*
			Scheuringipollenites
R	E		b.—ZONATES, PARASACCITES, *Brevitriletes*
			a.—PARASACCITES, *Scheuringipollenites*,
	R		*Brevitriletes*, apiculates
	1		
Karharbari			PARASACCITES, PLICATIPOLLENITES, *Brevitriletes*, *Callumispora*

The upper limit of the Barakar palynoflora is not very sharply defined at present except that the prolific miofloral of the Barakar suddenly declines in diversification, as the coal facies die out, and certain forms of *Densipollenites* and *Barakarites* become significant. (BHARADWAJ, SAH & TIWARI, 1965; SRIVASTAVA & MAHESHWARI, 1974) Although we accept this point of change as a marker for Barakar/Barren Measures for the present, more detailed work in such transition areas is necessary for better results.

On the lines of earlier syntheses cited above, as well as on the line of approach adopted in the present work, the limits of the Barakar palynoflora are suggested here as given in Table 2. In principle, the onset of any trend of miofloral break determines the line of demarcations while the dominance of a genus or two, marks the full-fledged commencement of the zone. The pattern of changing combinations in the generic members of miofloras within a zone determines the "place variants" or "time variants" in a narrower time-plane.

CONCLUSIONS

The conclusions derived in the present paper are summarised as follows:

1. The Barakar basins (Lower Gondwana basins in general) were inter-connected to form a definite system of drainage and the coal was formed by the drifted as well as local plant material. This is supported by the basic continuity in a set pattern in the miofloral constituents in these basins.
2. In the Barakar Stage four miofloral lines have been drawn, which demarcate the setting-in of the miofloral breaks; these lines from older to younger horizons are (i) *Monosaccate/zonate/apiculate*-line (ii) *Scheuringipollenites*-line (iii) *Striate-disaccate*-line (iv) *Densipollenites*-line.
3. These lines divide the Barakar into 3 palynological zones. These zones from olde to younger horizons are named as Zone B-I, Zone B-II and Zone B-III, and are likely to correspond in most cases with Lower, Middle and the Upper Barakar Stages respectively.
4. Laterally, the inter-basinal relationships of miofloras indicate microclimatic changes from one region to another. In the Zone B-I, the changing combinations of zonates with monosaccates, apiculates and varitriletes suggest that they are either the age equivalents of each other i.e. the lateral variants, or the finer time variants. In Zone-II the changing combination of *Scheuringipollenites* with apiculates, striates and *Latosporites* is indicative of the place, or finer time difference.
5. The Lower limits of Barakar palyno-flora are proposed to commence with the end of the second monosaccate zone of the Talchir Series and the appearance of significant zonates and apiculates along with the monosaccate subdominance.
6. The Lower Barakar miofloras (Zone B-I) are characterized by the changing partnership of the monosaccates/zonates/apiculates/varitriletes; such an arrangement appears to correspond to the basinal "regions" along the drainage system.
7. The Middle Barakar palynoflora (Zone B-II) commences with the *Scheuringipollenites*/apiculate-partnership and flourishes in the *Scheuringipollenites* superdominance, ultimately it shows a closing phase with *Scheuringipollenites*, *Faunipollenites* and *Latosporites* membership.
8. The Upper Barakar mioflora (Zone B-III) is a sudden reversal of the preceding one in having dominant striate disaccate with significant *Scheuringipollenites*. *Barakarites* is introduced as a qualitative, rare genus. The upper part of this zone contains more diversified striate-disaccate and a bit of *Densipollenites*.

9. The same flora continues in the Barren Measures but with the significance of *Densipollenites* and relatively more of *Barakarites*.
10. In keeping these lines in view, more successional studies are required to be undertaken to fill the gaps between the link coalfields along the inter-basinal lines. Also, more of Barakar/Barren Measures as well as Talchir/Coal Measures transition is to be studied for a better picture at those particular points.

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